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International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : H04B 10/08, 10/17	A1	(11) International Publication Number: WO 97/23964 (43) International Publication Date: 3 July 1997 (03.07.97)

(21) International Application Number: PCT/GB96/03144

(22) International Filing Date: 19 December 1996 (19.12.96)

(30) Priority Data:
9526176.4 21 December 1995 (21.12.95) GB

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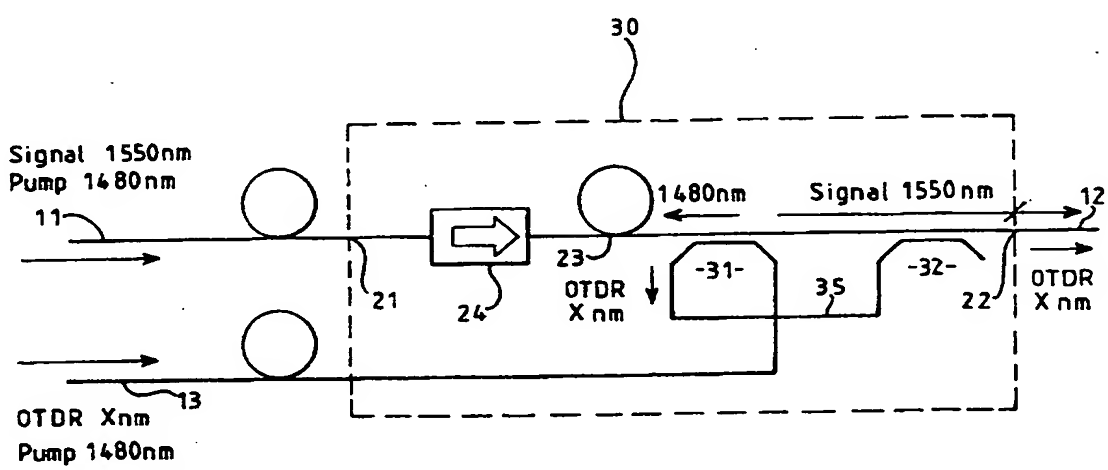
(81) Designated States: JP, US, European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.

(54) Title: AMPLIFIER FOR A FIBRE OPTIC COMMUNICATION SYSTEM



(57) Abstract

An amplifier (30) for a fibre optic communication system is provided. The amplifier, preferably a remote optically pumped amplifier (ROPA), is adapted to provide improved utilisation of optical time domain reflectometry (OTDR) for detection and analysis of faults on fibres of the fibre optic communication system. The amplifier (30) has an input port (21), an output port (22), an amplifying means (23) for amplifying traffic signals received at the input port (21), a blocking means such as an isolator (24) to prevent traffic signals passing towards the input port (21) from the direction of the output port (22) after amplification, and means such as a bypass path (35) which does not pass through the isolator (24) to allow OTDR signals to pass through the amplifier (30) in either direction.

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AMPLIFIER FOR A FIBRE OPTIC COMMUNICATION SYSTEM

The invention relates to an amplifier for a fibre optic communication system. The invention is especially suitable for a remote optically pumped amplifier (ROPA), and is directed particularly to the improved utilisation of optical time domain reflectometry (OTDR) for detection and analysis of faults on fibres of the fibre optic communication system.

A typical fibre optic communication system comprises a first terminal station at which traffic signals are sent, a second terminal station at which traffic signals are received, and a fibre trunk extending between the two. More complex systems may be provided in known manner by provision of means to allow sending of signals between the second terminal station and the first terminal station, and also for provision of signals to or from one or more branch stations branching off along spurs from the main trunk: the teaching that follows can be generalized to such systems by the man skilled in the art.

Frequently, such systems will be designed to carry signals over a great distance - in such cases, it is generally necessary to provide amplifiers on the fibre trunk to amplify the traffic signals, which will otherwise attenuate gradually along the fibre trunk. Different forms of amplifier are available, though a particularly suitable amplifier for this purpose comprises an erbium doped fibre. When the erbium doped fibre is pumped optically with light in the vicinity of 1480 nm, traffic signals at 1550 nm, which is a particularly suitable wavelength for passage along optical fibre (as losses are low), passing through the erbium doped fibre are amplified. It is appreciated that another doped fibre amplifier could be employed instead of an erbium doped fibre, and that the invention is also applicable thereto.

Where systems are adapted to carry signals over a great distance, it will often be the case that much of the trunk fibre, and hence, typically, the amplifiers, will be difficult to access. This is generally the case where the fibre trunk comprises in part a submarine cable to allow fibre optic communication across a body of water. In such cases, it is particularly desirable to minimize the possibility that access to the amplifiers will be required. One course of action to achieve this is to simplify the structure of the amplifiers, particularly by design to exclude all components requiring electrical power - this simplifies the system by obviating any need for provision of electrical power to or at the amplifier, and prevents faults relating to electrical malfunction from arising.

A remote optically pumped amplifier (ROPA) can be designed not to include any electrical components. A basic ROPA design is shown in Figure 1. A ROPA unit 10 is provided with an input port 21 to receive signals from a first terminal station along a traffic signal input fibre 11 of a first part of the fibre trunk and an output port 22 to provide signals to a second terminal station along a second part of the fibre trunk along a traffic signal output fibre 12. The ROPA comprises an amplifying means 23, which is here an erbium doped fibre. Such an amplifying means amplifies in both directions: it is therefore necessary also to include an optical isolator 24 on the traffic signal path to reduce noise - typically this could be situated between the erbium doped fibre 23 and the input port 21 to prevent amplified backscatter of signals into the first part of the fibre trunk.

The design shown in Figure 1 employs double pumping of the erbium doped fibre to increase efficiency. The first part of the fibre trunk comprises two fibres, a traffic signal input fibre 11 and a further pumping signal fibre 13. Both are received at input port 21, where a

separate path is provided for the pumping signals provided on pumping signal fibre 13 - these continue along a separate path until they are combined on to the traffic signal optical path through the amplifier at a fibre optic coupler 25. The coupler is adapted such that signals at a traffic signal wavelength (typically 1550 nm) do not cross between fibres of the coupler, but so that signals at the pumping light wavelength (typically 1480 nm) will do so. Light is thus provided from the pumping signal fibre to erbium doped fibre 23, supplementing pumping light also provided on the traffic signal input fibre 11, which passes along with the traffic signals through isolator 24 and into the erbium doped fibre 23. It is possible to dispense with the separate pumping signal fibre 13 and to provide pumping light on the traffic signal fibre alone - this is a simpler arrangement, but does not provide as efficient pumping.

The ROPA shown in Figure 1 is termed a post-ROPA, as it is pumped by pumping light from a terminal station which also provides traffic signals. A ROPA may also be designed to be pumped by pumping light from a terminal station which receives traffic signals - such a ROPA is termed a pre-ROPA. In such a case, pumping light would be provided along traffic signal output fibre 12 (in the opposite direction to the traffic signals) rather than along the traffic signal input fibre 11. If used, the further pumping signal fibre 13 would accompany the traffic signal output fibre 12 to output 22. It is of course possible for pumping light to be provided from a source other than the first trunk fibre part or the second trunk fibre part, but this is in practice unlikely to be as convenient. A simple system having a first terminal station 1, a second terminal station 2, a post-ROPA 10 and a pre-ROPA 15 is illustrated in Figure 2.

A particularly useful technique for identifying the presence of faults or other defects along a fibre optic system is Optical Time Domain Reflectometry (OTDR). This is a well known technique - an appropriate method for use in a system such as that in Figure 2 is to supply a pulse signal instead of a normal traffic signal at terminal station 1 from OTDR means within the terminal station (it is also possible for this to be done from the other terminal station 2). The pulse is transmitted along the fibre, and faults or other defects on the fibre will backscatter a part of the signal, typically in a frequency-dependent manner. The backscattered signal is then detected at the terminal station 1, and the travel time and the frequency response analysed to determine the position and the nature of the fault.

The effective range of OTDR is typically about 150-200 km, giving in theory the possibility of OTDR analysis along the whole length of a system of a length of 300-400 km. This is however not possible with ROPAs according to the design shown in Figure 1. This is because the presence of the isolator 24 renders the central portion of the fibre trunk inaccessable to OTDR - OTDR signals sent from terminal 1 can pass through the isolator 24 in post-ROPA 10, but the resulting backscattered signals cannot pass through it, whereas OTDR signals sent from terminal 2 cannot pass through the isolator 24 of the pre-ROPA 15 at all.

While prior art ROPAs are advantageous in that they allow fibre optic communication without need for electrical components on the trunk fibre, the parts of the trunk fibre separated from any terminal station by a ROPA are inaccessable to OTDR. It would therefore be desirable to provide an arrangement which had the advantages provided by ROPAs, but in which there were no barrier to OTDR on the trunk fibre.

Accordingly, the invention provides an amplifier for a fibre optic communication system, comprising:

an input port for connection to a first trunk fibre part;

an output port for connection to a second trunk fibre part;

an amplifying means for amplifying traffic signals received at the input port;

a blocking means to prevent traffic signals entering the amplifier at the input port from passing out of the input port towards the source of traffic signals after amplification from the amplifying means; whereby the blocking means does not prevent optical time domain reflectometry (OTDR) signals from passing through the amplifier both from the input port to the output port and from the output port to the input port.

Advantageously, the amplifier is a ROPA, and the amplifying means is an erbium doped fibre. In different embodiments, the amplifier can be adapted to receive OTDR signals, traffic signals, and optionally pumping light on the same fibre, or alternatively to receive OTDR signals and optionally pumping light on one fibre, and traffic signals and optionally pumping light on another fibre. Advantageously, with appropriate selection of OTDR wavelength, the OTDR signal is capable of amplification by the amplifying means, and is routed through the amplifier in such a manner as to pass through the amplifying means.

In a further aspect, the invention provides a fibre optic communication system, comprising: a first terminal station for sending traffic signals; a second terminal station for receiving traffic signals; a trunk fibre between the first terminal station and the second terminal station, the trunk fibre having thereon one or more amplifiers of the type indicated above; and OTDR

means at the first terminal station and/or the second terminal station for detection and analysis of faults on the trunk fibre.

Specific embodiments of the invention are described below, by way of example, with reference to the accompanying drawings, in which:

Figure 1 shows a prior art ROPA structure;

Figure 2 shows a simple fibre optic communication system employing a post-ROPA and a pre-ROPA;

Figure 3 shows a post-ROPA providing a first embodiment of an amplifer according to the invention;

Figure 4 shows a pre-ROPA providing a second embodiment of an amplifier according to the invention;

Figure 5 shows a post-ROPA providing a third embodiment of an amplifier according to the invention;

Figure 6 shows a post-ROPA providing a fourth embodiment of an amplifier according to the invention; and

Figure 7 shows a pre-ROPA providing a fifth embodiment of an amplifier according to the

invention.

Figure 8 shows a post-ROPA providing a sixth embodiment of the invention.

Figure 9 shows a post-ROPA providing a seventh embodiment of the invention.

Figure 10 shows a pre-ROPA providing an eighth embodiment of the invention.

Figure 11 shows a pre-ROPA providing a ninth embodiment of the invention.

Figure 3 shows a post-ROPA which provides a first embodiment of an amplifier according to the invention. The amplifier 30 has an input port 21 for connection to a first trunk fibre part. In the case illustrated, the first trunk fibre part has two fibres: a traffic signal input fibre 11 and an OTDR signal fibre 13. Both these fibres also carry pumping light: in alternative embodiments, pumping light may be carried by only one of the fibres (or in the case of an amplifier which requires no external pumping, none). It will generally be most convenient for both pumping light and OTDR signals to emanate from the nearest terminal station (and so travel down the same trunk fibre part). The amplifier 30 also has an output port 22, connected to a traffic signal output fibre 12 for onward transmission of the traffic signals (and also the OTDR signals) along a second trunk fibre part.

An amplifying means 23 is provided in the form of an erbium doped fibre for amplifying traffic signals received at the input port 21. A blocking means is provided in the form of an isolator 24 is provided to prevent traffic signals from passing (by reflection or otherwise)

towards the input port 21 from the direction of the output port 22. In these aspects, the amplifier 30 is essentially similar to the amplifier 10 shown in Figure 1.

Amplifier 30 differs from the prior art amplifier 10 in that means are provided to allow OTDR signals to pass through the amplifier in either direction. Here, a bypass path 35 is provided through the amplifier 30 which does not go through the isolator 24. The bypass path extends between the input port 21, where it is connected to the OTDR signal fibre 13, and a coupler 32 which provides connection to the traffic signal path through the amplifier 30. The bypass path 35 is adapted such that OTDR signals can pass through the amplifier 30 from the input port 21 to the output port 22 in either direction without passing through the isolator, thus enabling OTDR measurement to be carried out on the traffic signal output fibre 12. OTDR is here carried out on a path which is essentially the same for both outward and backscattered signals. This is achieved by a wavelength division multiplexing means on the bypass path adapted to route signals at an OTDR signal wavelength away from the isolator. In the present case the wavelength division multiplexing means comprises a first fibre coupler 32 which is adapted to allow transfer of signals at the OTDR wavelength between fibres of the coupler, but not to allow transfer between fibres of signals at a traffic signal wavelength (in the present case 1550 nm, a typical value for use with erbium doped fibre amplifiers). This means that OTDR signals arriving at first coupler 32 along bypass path 35 pass through to output port 22 and the traffic signal output fibre 12, and OTDR signals arriving at output port 22 from traffic signal output fibre 12 travel the opposite route. Traffic signals, however, may only travel along the traffic signal path between input port 21 and output port 22 and cannot be transferred on to the bypass path 35 from either direction.

The effect of this arrangement is that OTDR signals provided along OTDR signal fibre 13 pass through amplifier 30 along bypass path 35. They are coupled on to the traffic signal path through the amplifier 30 for onward passage through output port 21 on to the traffic signal output fibre 12. The traffic signal output fibre 12 is thus, in contrast to the prior art, susceptible of OTDR analysis - backscattered signals will take the same route (in the opposite direction) back to the source of the OTDR signals. It should however be noted that a different means or arrangement will be needed for analysis of the traffic signal input fibre 11, as the OTDR signal provided along the OTDR signal fibre 13 does not pass at any stage through traffic signal input fibre 11.

At a point on the bypass path 35 between the input port 21 and the first coupler 32, there is a second coupler 31. This second coupler 31 is adapted to allow pumping light provided on the OTDR signal fibre 13 to be provided to the erbium doped fibre 23 - in this respect, coupler 32 is similar in function to coupler 25 in amplifier 10 of Figure 1. However, coupler 31 must also be adapted to prevent exchange of OTDR signals with the traffic signal path at this point. Second coupler 31 is therefore adapted so that signals at a pumping light wavelength (typically, as here, 1480 nm for pumping of an erbium doped fibre) transfer between fibres of the second coupler 31, whereas signals at the OTDR wavelength do not, but instead continue along the bypass path 35.

Couplers 31 and 32 are in this case fused fibre 3dB optical couplers, treated in known matter to have a wavelength dependent transfer characteristic between the fibres of the couplers. Advantageously for this design, an OTDR signal wavelength is chosen which is between the pumping light wavelength and the traffic signal wavelength - in the present case, this leaves

a range between 1480 nm and 1550 nm. As is discussed further below, it may also be advantageous to select an OTDR signal wavelength which is within the effective range amplifiable by an erbium doped fibre (approximately 1530-1560 nm), although it is desirable that the OTDR signal wavelength be spaced adequately from traffic signal wavelengths (and indeed from the pumping light wavelength) to prevent any interference effects from arising. 1538 nm is therefore a particularly suitable choice for the OTDR signal wavelength. It should however be appreciated that it is entirely possible for different OTDR signal wavelengths to be used, even wavelengths which are significantly outside the range available between the pumping light wavelength and the traffic signal wavelength.

By appropriate coupler choice and, if appropriate, by rearrangement of the couplers, it is also possible to use arrangements of this type in which the OTDR signal is provided on the traffic signal input fibre 11 but the reflected OTDR signal passes out through OTDR signal fibre 13. The couplers need to be arranged such that OTDR light admitted through traffic signal input fibre 31 passes through the ROPA on to traffic signal output fibre 12, but such that reflected light entering from traffic signal output fibre 12 is diverted on to a different path out through OTDR signal fibre 13. The advantage of this arrangement is that the same OTDR signal can be used to evaluate the traffic signal path both before and after the ROPA.

Figure 4 shows a pre-ROPA which provides a second embodiment of an amplifier according to the invention. The operating principle of amplifier 40 shown in Figure 4 is essentially the same as that of amplifier 30 shown in Figure 3, but structural modifications necessary for its use as a pre-ROPA are provided. The OTDR signal fibre 13 is provided in the second trunk fibre part together with the traffic signal output fibre 12, and connection of the OTDR

signal fibre 13 to the bypass path 45 is effected through output port 22. The second coupler 41 to drop the pumping light to the erbium doped fibre 23 is provided between the erbium doped fibre 23 and the isolator 24, rather than as in amplifier 30, where second coupler 31 is connected between the erbium doped fibre 23 and the first coupler 32 (and the output port 22). Similarly, the first coupler 42 is positioned between the input port 21 and the isolator 24, rather than as for the first coupler 32 in amplifier 30, which is positioned between the output port 22 and the second coupler 31 (and the erbium doped fibre 23). The effect, however, is essentially the same: OTDR signals provided on OTDR signal fibre 13 pass on to bypass path 45, pass through the second coupler 41 without switching fibres, and then after switching fibres in coupler 42 pass out through the input port 21 on to traffic signal input fibre 11. Backscattered signals travel the same route in the opposite direction. Faults on traffic signal input fibre 11 can thus be detected and analyzed. In this case, separate OTDR means or arrangements are required to locate and analyse faults on traffic signal output fibre 12.

As for the Figure 3 embodiment, modification can be made to the coupler arrangements such that the OTDR signal is supplied from OTDR fibre 13, but such that the reflected OTDR signal passes through the ROPA on to traffic signal output fibre 12 along with the traffic signals (in which event the reflected OTDR signal will also be amplified).

Figure 5 shows a post-ROPA providing a third embodiment of an amplifier according to the invention. In this case, a different wavelength division multiplexing means is used: amplifier 50 comprises a first three-port optical circulator 51 and a first fibre Bragg grating 53 in place of the first coupler 32 (and also the second coupler 31) of amplifier 30. It is necessary for

the circulator 51 to allow full circulation (first port to second port, second port to third port, and third port to first port) in this design. Such a circulator could be replaced, for example, by three conventional three port circulators (or alternatively by three fibre optic couplers) in a triangular arrangement. The bypass path 55 extends from the input port 21, where it connects to the OTDR signal fibre 13, to the first port of circulator 51. The second and third ports of circulator 51 connect to the traffic signal path through the amplifier 50. The second port is connected to a first optical path leading from the input port 21, passing through the isolator 24 and the erbium doped fibre 23. Traffic signals thus arrive from this port, and are circulated through to the third port of circulator 51, which is connected to the output port 22, and hence to the traffic signal output fibre 12.

OTDR signals from OTDR signal fibre 13 pass along the bypass path 55 and out through the second port of the first circulator 51 along the first optical path in the direction of the amplifier 23 and the isolator 24. To prevent the OTDR signals from reaching the isolator 24, the first fibre Bragg grating 53 is provided on the first optical path. The grating 53 is a notch reflection filter, adapted to reflect light at the OTDR wavelength, but to allow transmission therethrough of both pumping light and traffic signals. The OTDR signals are thus reflected by the first grating 53 back to the second port of circulator 51, and pass through the third port out on to the traffic signal output fibre 12, together with the traffic signals.

Amplifier 50 thus allows OTDR analysis of traffic signal output fibre 12. Backscattered signals take a slightly different route back to the OTDR signal input fibre 13. The backscattered signals arrive at the third port of circulator 51 from traffic signal output fibre

12 through output port 22, and are then circulated to the first port, from where they pass out directly back along bypass path 55 and out along OTDR signal input fibre 13 through input port 21.

Pumping light provided from OTDR signal input fibre 13 takes the same route as the OTDR signal, but is not reflected by the grating 53. It therefore passes through to the erbium doped fibre 23 to pump it.

The design of Figure 5 is advantageous, in that a simpler fibre path is provided and use of a fibre Bragg grating allows a freer choice of OTDR wavelength. A modified form of the design of Figure 5 is shown in Figure 6, which shows a post-ROPA providing a fourth embodiment of an amplifier according to the invention. Amplifier 60 is essentially similar to amplifier 50 of Figure 5, but the positions of erbium doped fibre 23 and grating 53 are reversed. This has the effect that the OTDR signal supplied from the OTDR signal fibre 13 passes twice through the erbium doped fibre 23. With appropriate choice of OTDR signal wavelength to lie within the optical amplifier gain bandwidth (approximately 1530-1560 nm), this arrangement leads to amplification of the OTDR signal and hence to an extension in the useful range of OTDR. This arrangement is not advantageous if the OTDR signal wavelength is outside the optical amplifier gain bandwidth, or if the amplifier is not pumped.

It is also possible for the present invention to be employed where no separate OTDR signal fibre is used, but instead a dual signal fibre is used to carry both traffic signals and OTDR signals (and also optionally pumping light). Such an arrangement is shown in Figure 7, which shows a pre-ROPA providing a fifth embodiment of an amplifier according to the

invention.

Amplifier 70 employs an adaption of the circulator and grating form of wavelength division multiplexing means shown in Figures 5 and 6 to a pre-ROPA. The equivalent in amplifier 70 to the first circulator 51 of amplifier 50 is first circulator 71. A first port of the first circulator 71 is connected to the bypass path 78, a second port is connected to the input port 21, and the third port is connected to a first optical path leading towards the output port 22 through the optical isolator 24. It is necessary for the circulator to employ full circulation: first port to second port, second port to third port, and third port to first port. Traffic signals pass in through the input port 21, then in through the second port and out through the third port of the first circulator 71, then to enter the isolator 24. OTDR signals entering circulator 71 from the bypass path 78 pass in through the first port and out throught the second port of the circulator 71, to pass out through input port 21 and on to traffic signal input fibre 11 to enable OTDR analysis of this fibre. Backscattered signals pass through input port 21 and circulator 71 (via second and third ports) on to the optical path towards the isolator 24, but are reflected before the isolator by the first fibre Bragg grating 73, which is adapted to reflect light at the OTDR signal wavelength (but to allow passage of traffic signals). The backscattered light is therefore again circulated through third and first ports of the first circulator 71 and passes on to the bypass path 78.

In amplifier 70, it is necessary for the bypass path to be recombined to the traffic signal path through the amplifier 70 before output port 22, as all signals must pass out on the dual signal fibre 14. This has to be done in such a manner that the traffic signals are prevented from passing along the bypass path 78, but so that the OTDR signals are routed along the bypass

path 78 and not into the isolator 24. If pumping light is provided, this must also be routed to the erbium doped fibre 23.

This is achieved by an arrangement employing a second three-port circulator 72 and second and third fibre Bragg gratings 74,75. The second three-port circulator 72, which also employs full circulation, has a first port connected to the output port 22, a second port connected to a second optical path towards the input port 21 (through erbium doped fibre 23 and isolator 24 respectively), and a third port connected to the other end of the bypass path 78. The OTDR signal input from dual signal fibre 14 passes in through the first port and out through the second port of the second circulator 72. This OTDR signal passes through erbium doped fibre 23 to second fibre Bragg grating 74. The OTDR signal is amplified if it falls within the optical amplifier gain bandwidth - the same position applies here as for Figures 5 and 6 in this regard, and the position of erbium doped fibre 23 and second Bragg grating 74 may be reversed in the same manner as there described if appropriate. Second Bragg grating 74 is a notch reflection filter reflecting light at the OTDR wavelength, but allowing traffic signals (and, if appropriate, pumping light) to pass therethrough. The OTDR signal thus reflected passes back through erbium doped fibre 23 to the second circulator 72, where it enters at the second port and passes out through the third port and on to the bypass fibre 78. Backscattered OTDR signals arriving at the second circulator 72 from the bypass fibre pass in through the third port and out through the first port, and thus pass back through the output port 22 on to the dual signal fibre. Pumping light, if provided on dual signal fibre 14, takes the same route as OTDR signals provided on this fibre - however, pumping light is absorbed by the erbium doped fibre 23 when it is reached.

Traffic signals pass out of the isolator 24 through the second grating 74 and the erbium doped fibre 23 to the second port of the second circulator 72. These signals are then circulated out through the third port on to the bypass path 78. To prevent traffic signals passing along this path, third fibre Bragg grating 75 is provided - this grating is adapted to reflect at the traffic signal wavelength (or wavelengths), but to allow OTDR signals to pass therethrough. Grating 75 therefore does not change the routing of OTDR signals, but causes the traffic signals to be reflected back to the third port of circulator 72 and out through the first port, to pass out through the output port 22 and on to the dual signal fibre 14.

Further embodiments of the invention are shown in Figures 8 and 9, showing a post-ROPA, and Figures 10 and 11, showing a pre-ROPA. In these embodiments, the blocking means to prevent return of traffic signals for the amplifier to the traffic signal input fibre is not an isolator, as for a conventional ROPA. Instead, a three-port circulator 84,94,104,114 replaces the isolator and also provides the desired routing for the OTDR signal.

In Figure 8, the traffic signal is provided along traffic signal input fibre 11, passes from first to second port of circulator 84 and out through amplifier 23 and traffic signal output fibre 12. Pumping light may also be provided from the traffic signal input fibre 11. Pumping light may also be provided, as shown, for the OTDR signal fibre 13, and coupled on to the main fibre to amplifier 23 through output coupler 81. The OTDR signal in this embodiment has different outward and return paths. The outward signal travels with the traffic signal until it is reflected. It then passes back from traffic signal output fibre 12, through amplifier 23, and in to the second port of circulator 84. The OTDR signal passes out through the third port of this circulator and out onto OTDR signal fibre 13 for detection. The OTDR signal

is thus amplified twice, as in the Figure 6 embodiment.

An alternative post-ROPA is shown in Figure 9. In this embodiment, the amplifier 23 is now located on the traffic signal input fibre side of the three port circulator, rather than on the traffic signal output fibre side. This renders it unnecessary for a coupler 81 as in Figure 8 to be provided, as pumping light provided on OTDR signal fibre 13 will be circulated back to amplifier 23. The OTDR signal will, as for Figure 8, be provided on traffic signal input fibre 11 and routed back after reflection on OTDR signal fibre 13.

It should be noted that unlike for the Figure 8 embodiment, the circulator of the Figure 9 embodiment must employ full circulation (as previously described). The Figure 9 embodiment also provides only single amplification for the OTDR signal, as opposed to the Figure 8 embodiment, where the OTDR signal will pass through amplifier 23 twice. However, the location of the "isolator" provided by the circulator 94 after the amplifier 23 may be advantageous in a post-ROPA in certain network configurations, which the skilled man could assess using his normal technical skill and judgement.

The pre-ROPA of Figure 10 is essentially similar in design. The OTDR signal here is provided on OTDR signal fibre 13, circulated from the first to the second port of circulator 104, and passes out through amplifier 23 onto traffic signal input fibre 11. The return signal again passes through amplifier 23, then through second and third ports of circulator 104 to traffic signal output fibre 12. In this design, pumping is only available from OTDR signal fibre 13, and not from traffic signal output fibre 12, because of circulator 104.

An alternative arrangement is shown in Figure 11. The Figure 11 arrangement differs from the Figure 10 arrangement in that the amplifier 23 is moved from the traffic signal output fibre side of the circulator 104 to the traffic signal input fibre side. This has a series of effects. Firstly, it is now possible to pump amplifier 23 from traffic signal output fibre 12 as well as from OTDR signal fibre 13. Secondly, the OTDR signal will only be amplified once by amplifier 23, rather than twice. Thirdly, the "isolator" is before the amplifier 23, rather than after - this may be advantageous in certain system designs, as could be understood by the skilled man using his normal technical skill and judgement. The choice of pre-ROPA arrangement employed will thus depend on the overall system design.

A potentially advantageous feature of the Figures 8 to 11 embodiments is avoidance of the use of Bragg filters, which may be a source of instability, particularly when used in conjunction with a high-gain amplifier.

It may be noted that the structures shown can be employed even where pumping light is not provided on any of the fibres shown - it may instead be provided on other, unillustrated fibres, or even not provided at all (for an appropriate choice of amplifier). The structures shown may be employed in any amplifier structure which employs an isolator or component with similar function apparently preventing one or both of the outward transmission and return of OTDR signals through the amplifier. The need for isolators in ROPA design renders the present invention especially suitable for use in that area. It may also be appreciated that specific components used in the embodiments may be replaced by components with equivalent functionality - for example, fibre Bragg gratings may be replaced by filters or other appropriate component to allow selective passage and reflection of chosen

wavelengths. By use of pre- and post-ROPAs according to embodiments of the invention in the system depicted in Figure 2, a system with substantial or even total OTDR analysis capability can be provided.

CLAIMS

1. An amplifier for a fibre optic communication system, comprising:

   an input port (21) for connection to a first trunk fibre part;

   an output port (22) for connection to a second trunk fibre part;

   an amplifying means (23) for amplifying traffic signals received at the input port;

   a blocking means (24,84,94,104) to prevent traffic signals entering the amplifier at the input port from passing out of the input port towards the source of traffic signals after amplification from the amplifying means;

   whereby the blocking means does not prevent optical time domain reflectometry (OTDR) signals from passing through the amplifier both from the input port to the output port and from the output port to the input port.

2. An amplifier as claimed in claim 1 and adapted for input of an OTDR signal at the input port (21) from the first trunk fibre part.

3. An amplifier as claimed in claim 1 and adapted for input of an OTDR signal at the output port (22) from the second trunk fibre part.

4. An amplifier as claimed in claim 2 or claim 3, wherein the port adapted for input of the OTDR signal is adapted for connection to a trunk fibre part with two fibres, a traffic signal fibre (11,12) and an OTDR signal fibre (13).

5. An amplifier as claimed in claim 2 or claim 3, wherein the port adapted for input of the OTDR signal is adapted for connection to a trunk fibre part with a dual signal fibre (14) to carry both traffic signals and OTDR signals.

6. An amplifier as claimed in any preceding claim and adapted such that the OTDR signals pass through the amplifying means (23) on at least one passage through the amplifier.

7. An amplifier as claimed in any preceding claim which is a remote optically pumped amplifier (ROPA).

8. An amplifier as claimed in claim 7, wherein the amplifying means is an erbium doped fibre located on a traffic signal path between the input port (21) and the output port (22).

9. An amplifier as claimed in claim 7 or 8 and adapted for provision of pumping light from either the first trunk fibre part or the second trunk fibre part.

10. An amplifier as claimed in claim 9 where dependent on claim 4, where the amplifier is adapted for provision of pumping light from both the traffic signal fibre (11,12) and the OTDR signal fibre (13).

11. An amplifier as claimed in claim 9 where dependent on claim 5, where the amplifier is adapted for provision of pumping light from the dual signal fibre (14).

12. An amplifier as claimed in any preceding claim, wherein the amplifier is adapted for provision of OTDR signals at a wavelength between that of pumping light and of traffic signals.

13. An amplifier as claimed in any preceding claim, wherein the blocking means is an optical isolator (24); and
a bypass path (35,45,55,78) is provided which does not pass through the optical isolator to allow OTDR signals to pass from the output port (22) to the input port (21).

14. An amplifier as claimed in claim 13, wherein the bypass path comprises wavelength division multiplexing means adapted to route signals at an OTDR signal wavelength away from the optical isolator (24).

15. An amplifier as claimed in claim 14, wherein the wavelength division multiplexing means comprises a first optical coupler (32,42) adapted to allow light at an OTDR signal wavelength to transfer between fibres of the first coupler, but not to allow light at a traffic signal wavelength to transfer between fibres of the first coupler.

16. An amplifier as claimed in claim 15 where dependent on claim 8, wherein the bypass path further comprises a second optical coupler (31,41) adapted to allow pumping light at a pumping light wavelength to transfer between fibres of the second coupler,

but not to allow light at the OTDR signal wavelength to transfer between fibres of the second coupler.

17. An amplifier as claimed in claim 16, wherein the bypass path (35,45) is connected to receive pumping light and OTDR signals from the OTDR signal fibre (13), wherein the path continues to the second coupler (31,41) which is connected to allow provision of pumping light to the erbium doped fibre (23), and wherein the path further continues to the first coupler (32,42) which is connected to allow OTDR signals to pass between the bypass path (35,45) and the port not adapted for input of the OTDR signals.

18. An amplifier as claimed in claim 14, wherein the wavelength division multiplexing means comprises a first three-port optical circulator (51,71) and a first Bragg grating (53,73) adapted to reflect light at an OTDR signal wavelength, wherein the three ports of the first circulator are connected, respectively, to the input port or output port of the amplifier, to a fibre of the bypass path (55), and to a first optical path to the optical isolator (24), wherein the first Bragg grating (53,73) is located on the first optical path to the optical isolator (24).

19. An amplifier as claimed in claim 18 where dependent on claim 8, wherein the erbium doped fibre (23) is on the first optical path between the first Bragg grating (53) and the optical isolator (24).

20. An amplifier as claimed in claim 18 where dependent on claim 8, wherein the first circulator (51) is connected to the output port and wherein the erbium doped fibre (23) is on the first optical path between the first Bragg grating (53) and the first circulator (51).

21. An amplifier as claimed in claim 18 where dependent on claim 5 wherein the amplifier further comprises a second three-port optical circulator (72) and second and third Bragg gratings (74,75), wherein the three ports of the second circulator (72) are connected, respectively, to the one of the input port and the output port not connected to a port of the first circulator, to a second optical path to the optical isolator, and to the fibre of the bypass path (78), wherein the second Bragg grating (74) is adapted to reflect light at the OTDR signal wavelength and is located on the second optical path, and wherein the third Bragg grating is adapted to reflect light at the traffic signal wavelength and is located on the fibre of the bypass path (78).

22. An amplifier as claimed in claim 21 where dependent on claim 8, wherein the second circulator (72) is connected to the output port, and wherein the erbium doped fibre (23) is on the second optical path to the second Bragg grating (74) and the second circulator (72).

23. An amplifier as claimed in any of claims 6 to 10 or 12 where dependent on claim 4, wherein the blocking means comprises an optical circulator (84,94,104) disposed on the main traffic signal path to route light passing through the amplifier from the direction of the traffic signal fibre of the output port on to the OTDR signal fibre.

24. An amplifier as claimed in claim 23, wherein the optical circulator is a three port circulator (84,94), having a first port connected to the traffic signal fibre (11) of the input port, a second port connected to the traffic signal fibre (12) of the output port, and a third port connected to the OTDR signal fibre (13).

25. An amplifier as claimed in claim 23, wherein the optical circulator (104) is a three port circulator having a first port connected to the OTDR signal fibre (13), a second port connected to the traffic signal fibre (11) of the input port, and a third port connected to the traffic signal fibre (12) of the output port.

26. An amplifier as claimed in any of claims 23 to 25, wherein the optical circulator (84,94,104) is adapted to circulate from any one port to the following port in sequence, including from the final port to the first port.

27. An amplifier as claimed in any of claims 23 to 26 where dependent on claim 8, wherein an optical coupler (81,101) is provided between one of the traffic signal fibres (11,12) and the OTDR signal fibre (13) to allow pumping light to be transferred from the OTDR signal fibre (13) for routing to the erbium doped fibre (23), but not to allow the OTDR signal to be transferred between OTDR signal fibre (13) and traffic signal fibre (11,12).

28. An amplifier as claimed in claim 27, wherein the erbium doped fibre (23) is located between an OTDR output of the optical coupler (81,91) and a port of the optical circulator (84,94).

29. An amplifier as claimed in claim 27, wherein an OTDR output of the optical coupler (101) is connected to a port of the optical circulator (104), and the erbium doped fibre (23) is connected to a next port in sequence of the optical circulation (104).

30. An amplifier as claimed in claim 24 where dependent on claims 2 and 8, wherein the erbium doped fibre (23) is located between the traffic signal input fibre (11) and the optical circulator (94).

31. An amplifier as claimed in any of claims 23 to 30, wherein at the port adapted for input of the OTDR signal, the OTDR signal is adapted to enter the amplifier on one of the traffic signal fibre (11,12) and the OTDR signal fibre (13) and after reflection is adapted to leave the amplifier on the other of the traffic signal fibre (11,12) and the OTDR signal fibre (13).

32. An amplifer for a fibre optic communication system substantially as described herein with reference to Figures 3 to 7 of the accompanying drawings.

33. A fibre optic communication system, comprising:

a first terminal station (11) for sending traffic signals;

a second terminal station (2) for receiving traffic signals;

a trunk fibre between the first terminal station and the second terminal station, the trunk fibre having thereon one or more amplifiers (10,15) as claimed in any preceding claim; and

OTDR means at the first terminal station and/or the second terminal station

for detection and analysis of faults on the trunk fibre.

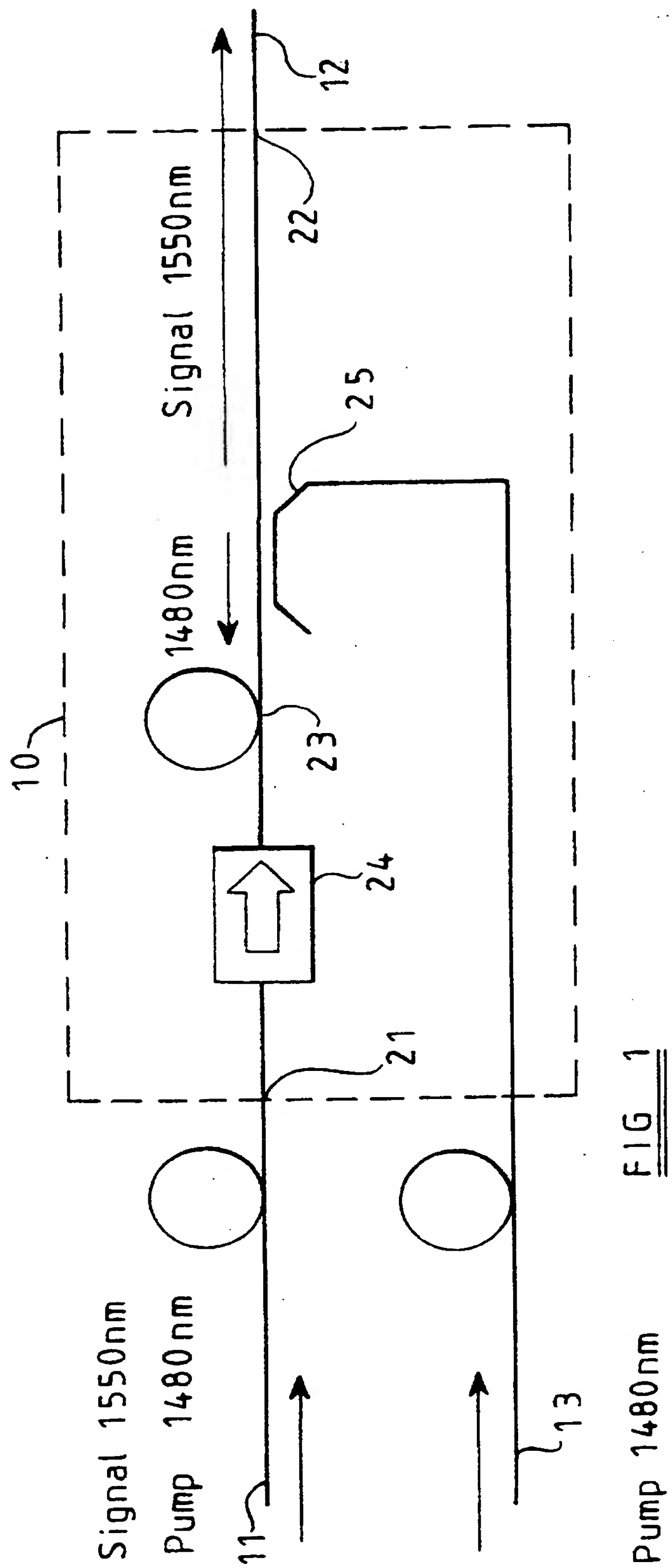

Signal 1550nm
12
22
25
1480nm
10
23
24
21
Signal 1550nm
Pump 1480nm
11
13
Pump 1480nm

FIG 1

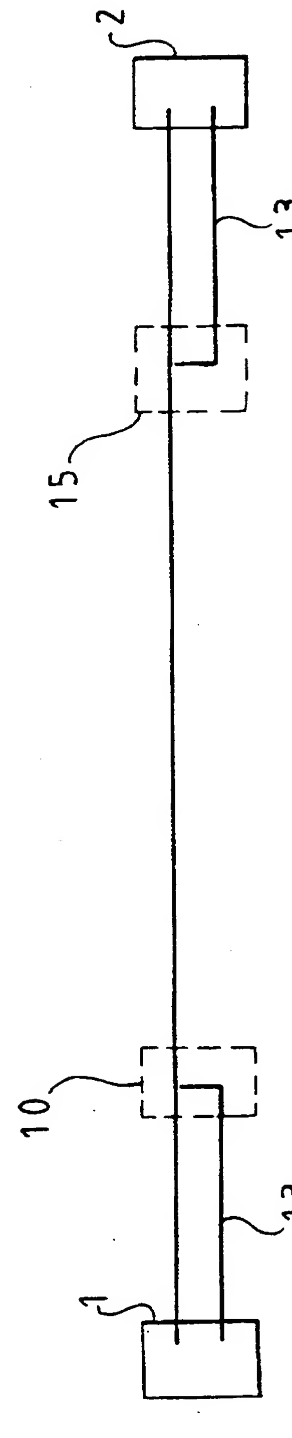

2
13
15
10
13
1

FIG 2

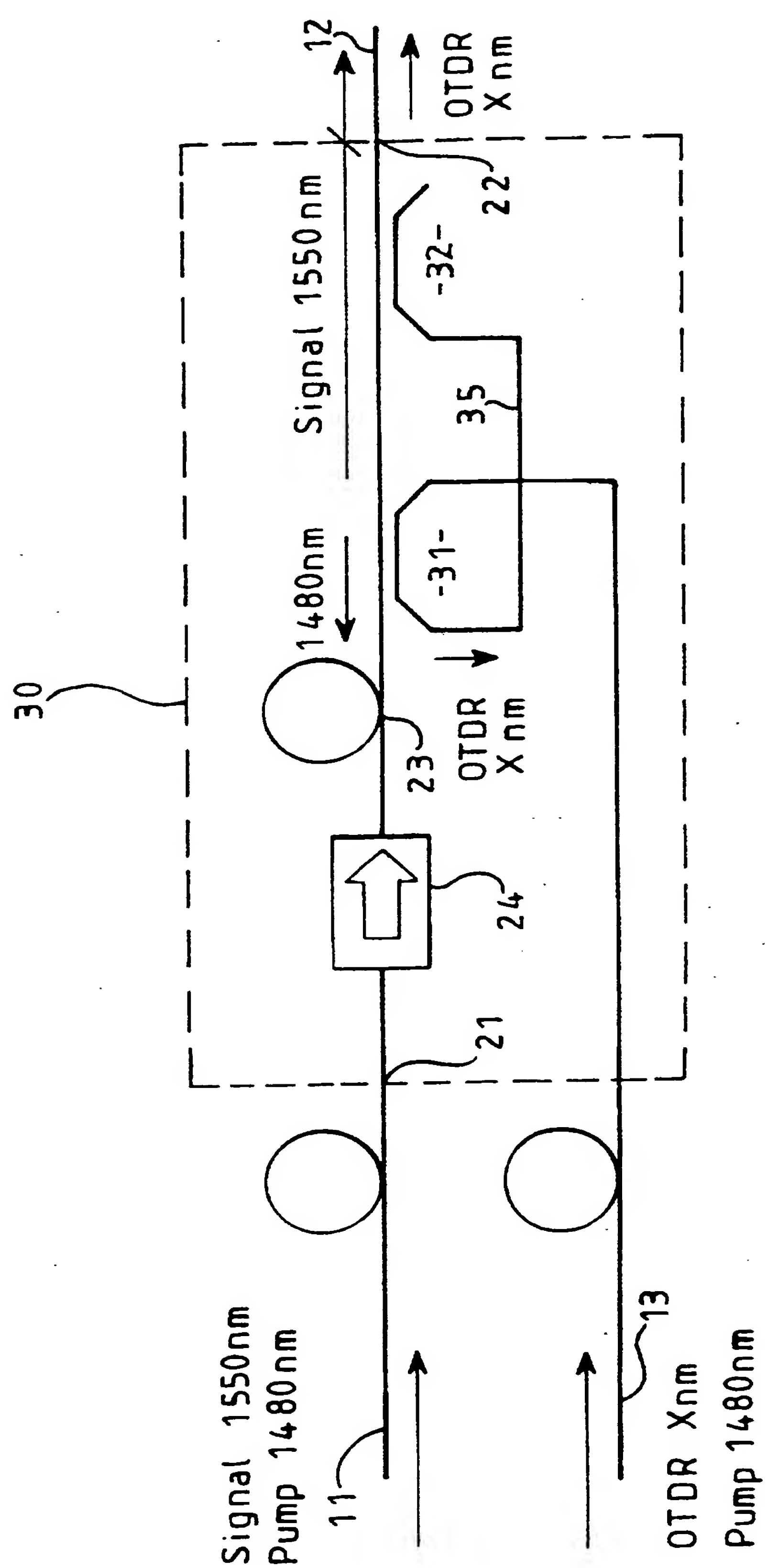

12
OTDR X nm
Signal 1550nm
22
-32-
35
-31-
1480nm
30
23
OTDR X nm
24
21
13
Signal 1550nm
Pump 1480nm
11
OTDR Xnm
Pump 1480nm

FIG 3

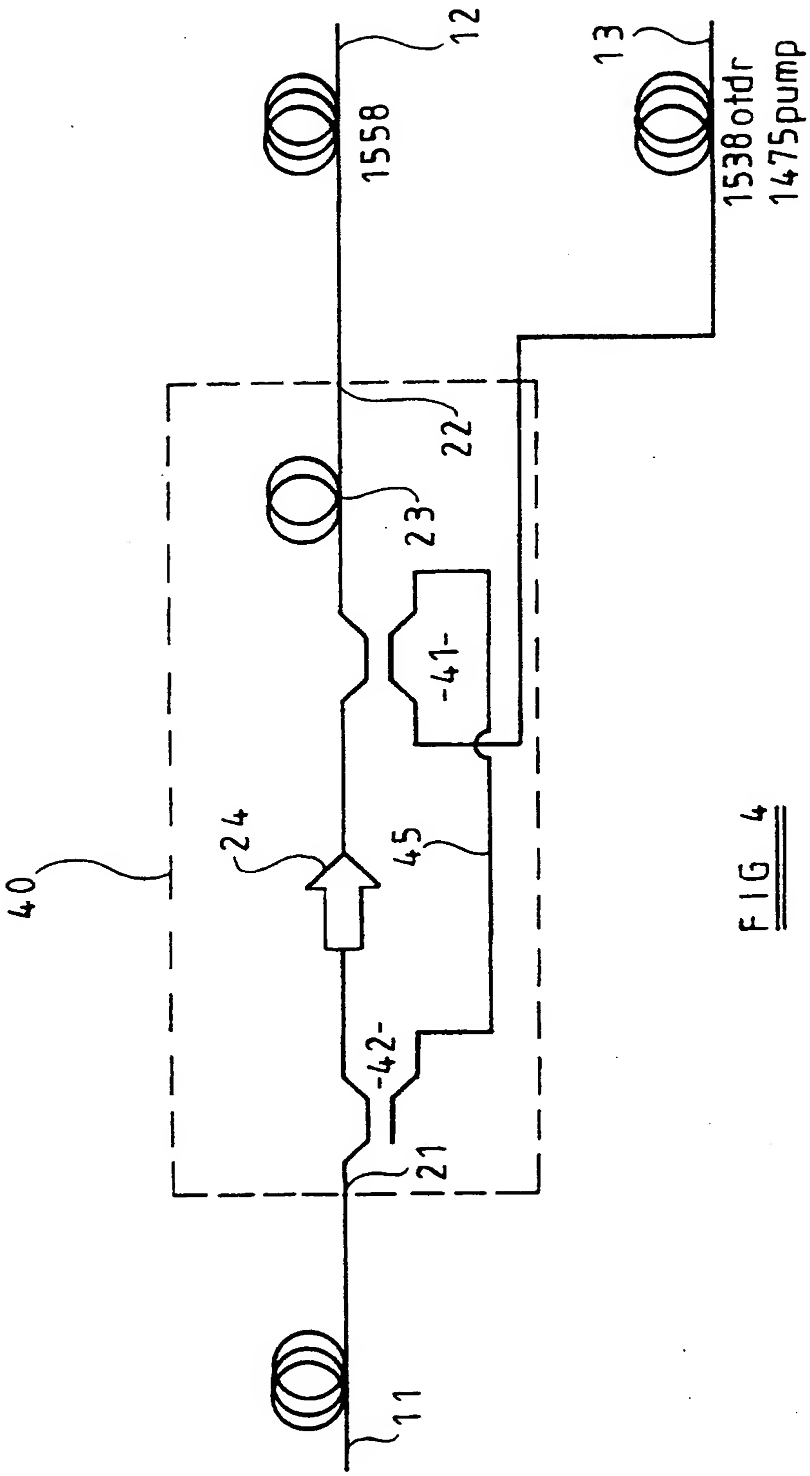


FIG 4

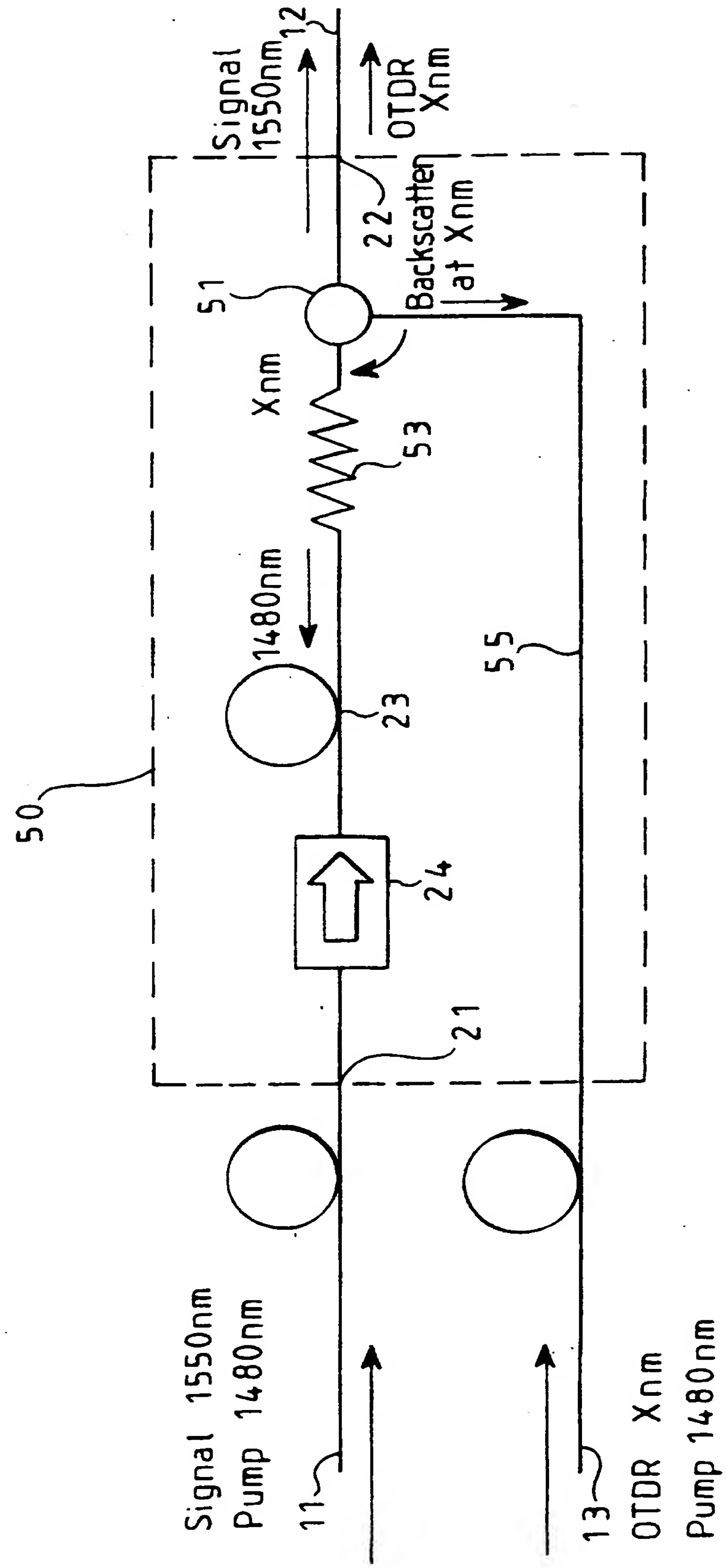

Signal 1550nm
12
OTDR Xnm
22
Backscatter at Xnm
51
Xnm
53
1480nm
55
23
50
24
21
Signal 1550nm
Pump 1480nm
11
13
OTDR Xnm
Pump 1480nm

FIG 5

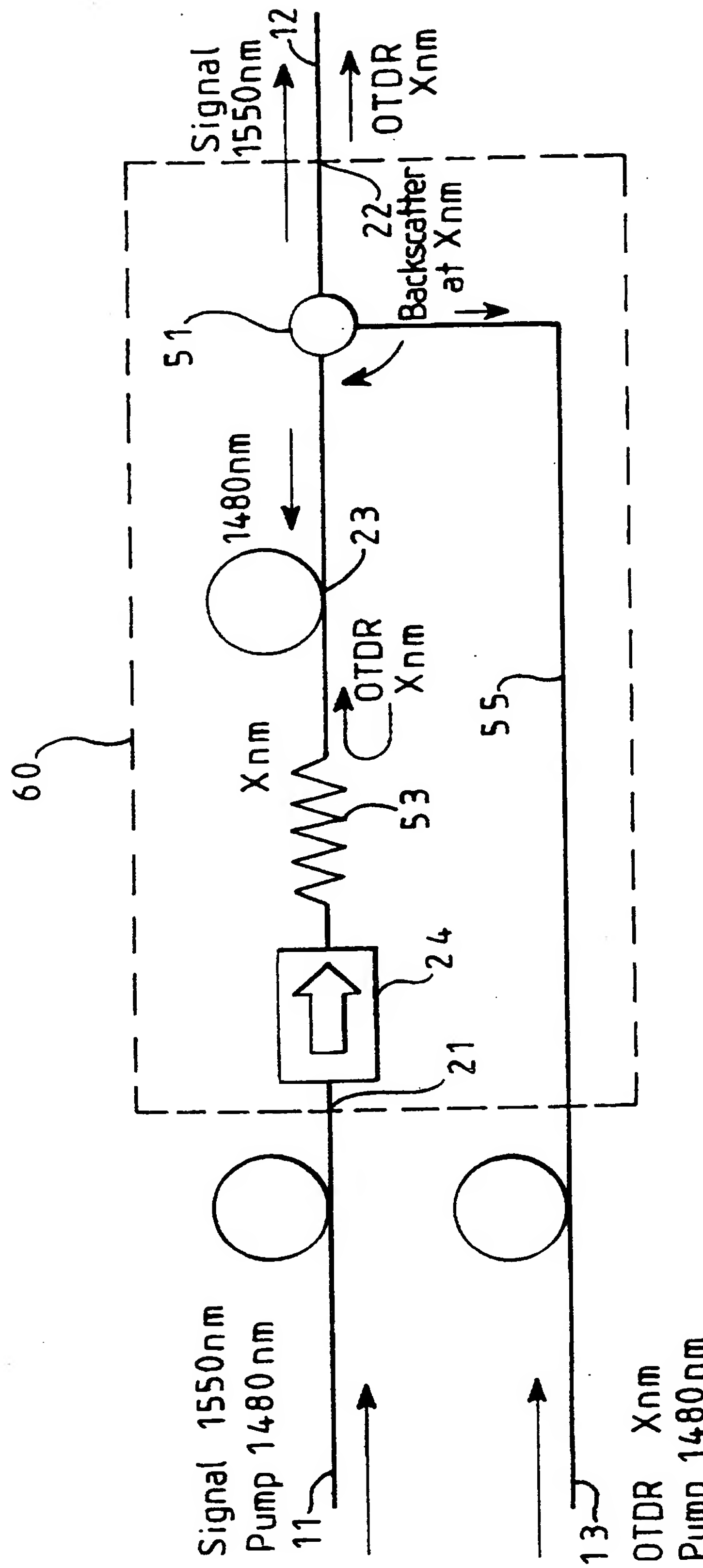
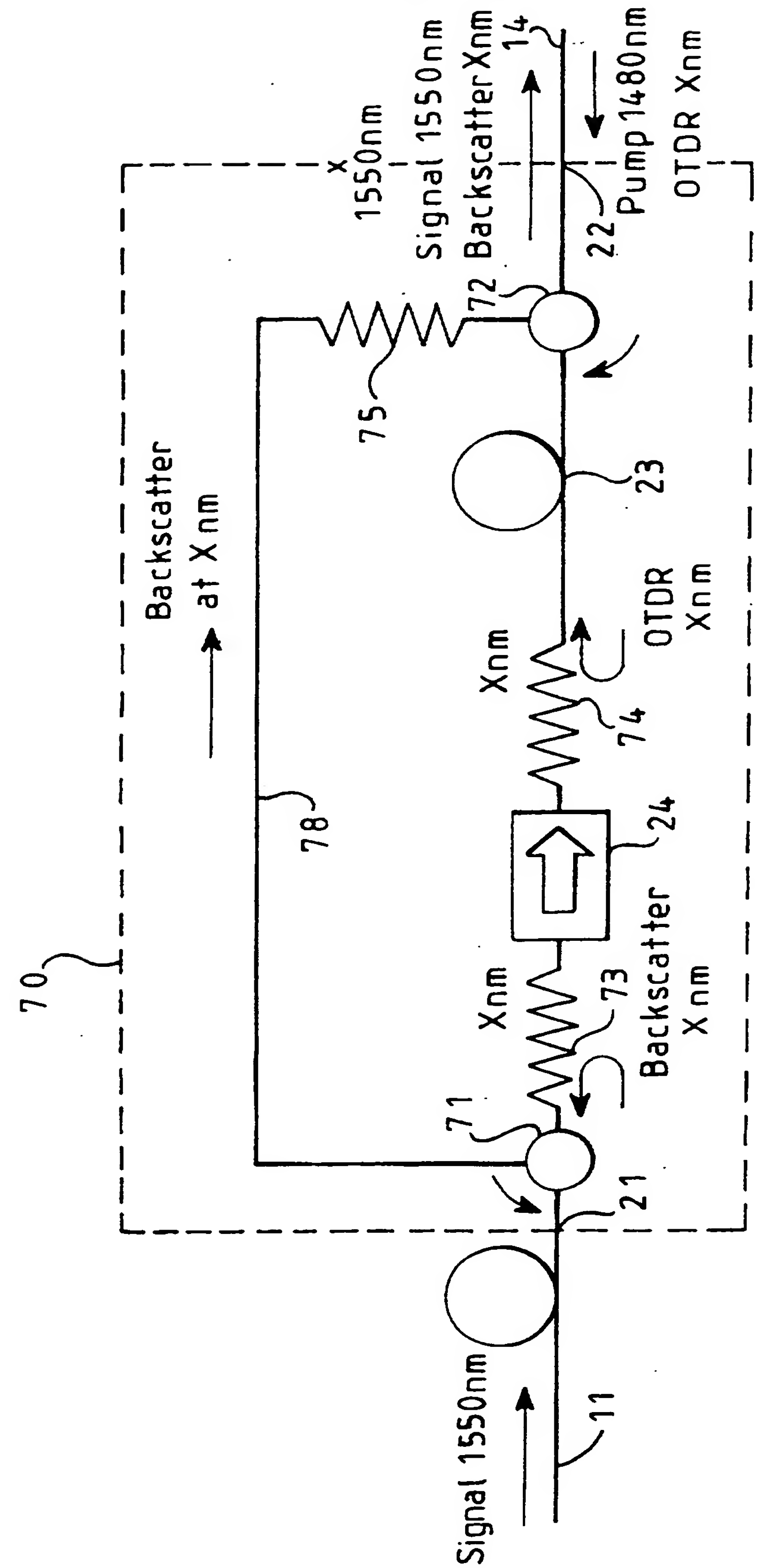

Signal 1550nm
12
OTDR Xnm
22
Backscatter at Xnm
51
1480nm
23
OTDR Xnm
Xnm
53
24
21
55
60
Signal 1550nm
Pump 1480nm
11
OTDR Xnm
Pump 1480nm
13

FIG 6



Signal 1550nm
11
21
71
73
Xnm
Backscatter Xnm
24
78
74
Xnm
OTDR Xnm
23
75
72
22
x
1550nm
Signal 1550nm
Backscatter Xnm
14
Pump 1480nm
OTDR Xnm
Backscatter at X nm
70

FIG 7

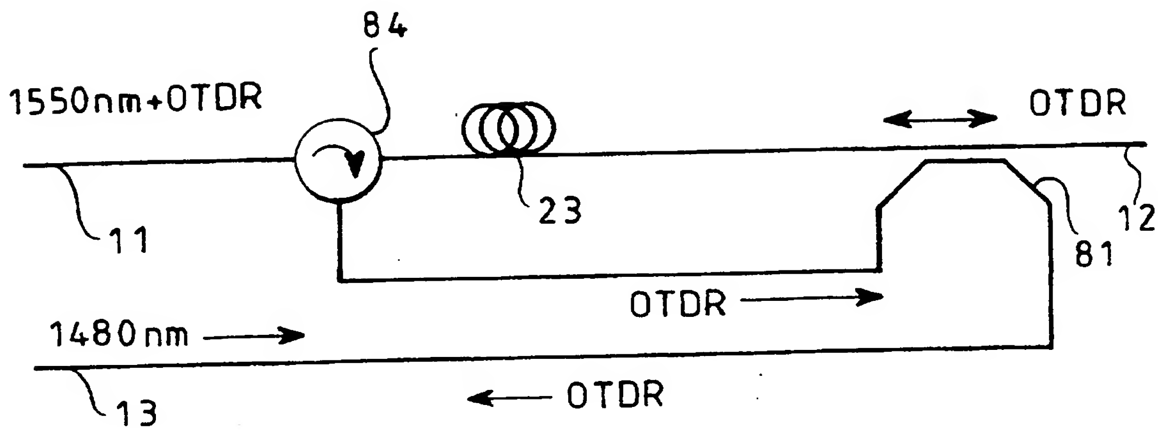

84
1550nm+OTDR
OTDR
23
11
12
81
OTDR
1480nm
13
OTDR

FIG 8

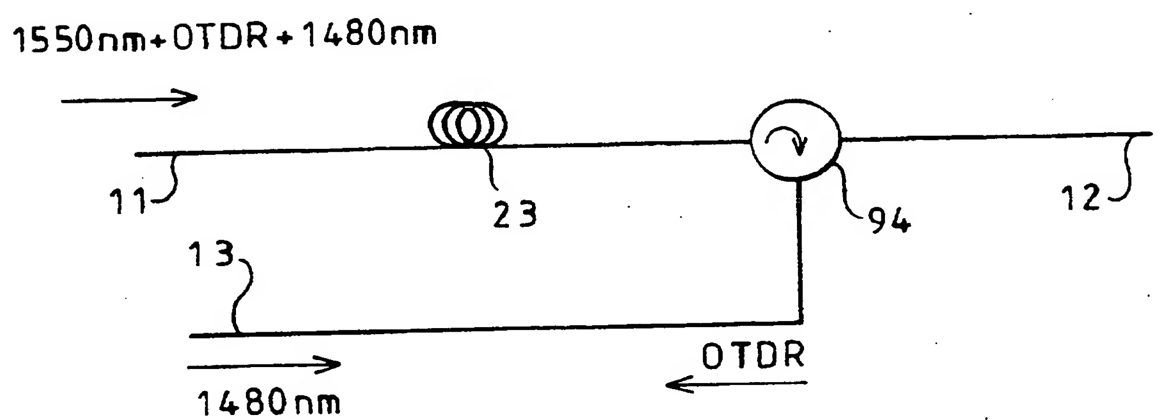

1550nm+OTDR+1480nm
11
23
94
12
13
OTDR
1480nm

FIG 9

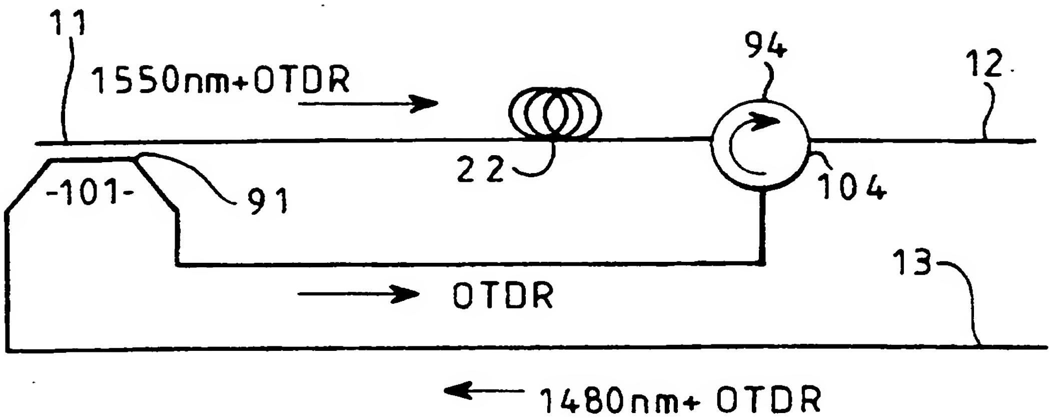

11
1550nm+OTDR
94
12
22
-101-
91
104
13
OTDR
1480nm+ OTDR

FIG 10

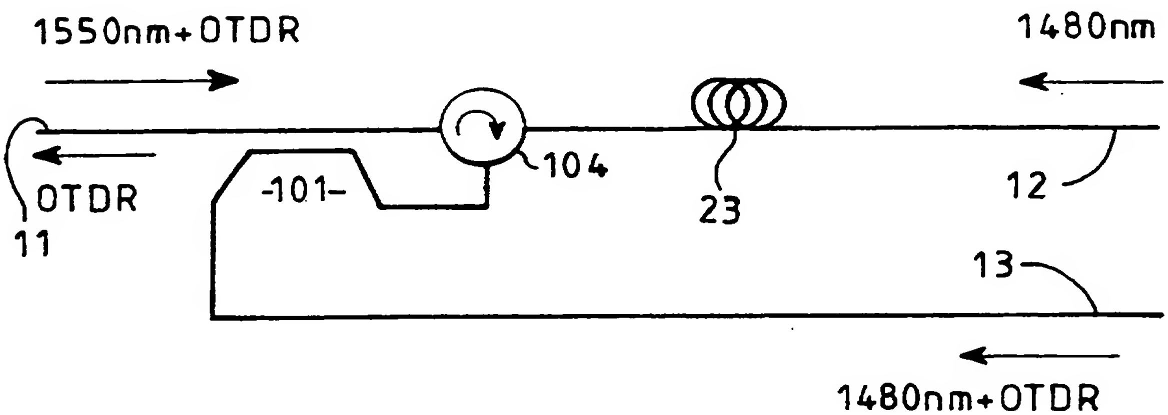

1550nm+OTDR
1480nm
104
-101-
OTDR
11
23
12
13
1480nm+OTDR

FIG 11

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 96/03144

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04B10/08 H04B10/17

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04B G01M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 467 080 A (SUMITOMO ELECTRIC INDUSTRIES) 22 January 1992 see column 5, line 53 - column 7, line 25 see column 7, line 42 - column 8, line 40 see column 9, line 31 - line 38 see column 9, line 49 - column 10, line 38 see figures 1-3	1,2,4-9, 13-17, 23,26,33
A		3,10-12, 18-22, 24,25, 27-32

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26 March 1997	17.04.97

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Williams, M.I.

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 96/03144

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 516 363 A (FURUKAWA ELECTRIC) 2 December 1992 see column 3, line 52 - column 4, line 5 see column 5, line 44 - column 6, line 24 see column 6, line 43 - column 7, line 22 see figures 1,2,4 ---	1,2,5,6, 13,33
X	IEEE PHOTONICS TECHNOLOGY LETTERS, vol. 7, no. 5, May 1995, NEW YORK US, pages 540-542, XP000506802 FURUKAWA ET AL: "Enhanced coherent OTDR for long span optical transmission lines containing optical fiber amplifiers" see page 540, right-hand column, line 4 - line 13 see figure 1 ---	1,2,4,6, 23
X	ELECTRONICS LETTERS, vol. 28, no. 6, 12 March 1992, STEVENAGE GB, pages 559-561, XP000287238 CHENG ET AL: "Novel fibre amplifier configuration suitable for bidirectional system" see page 560, left-hand column, paragraph 3 - right-hand column, paragraph 2; figures 1,2 ---	1,2,5,6, 12,13,33
X	JOURNAL OF LIGHTWAVE TECHNOLOGY, vol. 10, no. 1, January 1992, NEW YORK US, pages 78-83, XP000273023 SATO ET AL: "Optical time domain reflectometry in optical transmission lines containing in-line Er-doped fiber amplifiers" see page 78, right-hand column, last paragraph - page 79, left-hand column, paragraph 1 see page 81, left-hand column, paragraph 2 see figures 1,2,8 -----	1-3,6,8

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INTERNATIONAL SEARCH REPORT

Information on patent family members

Intern   nal Application No
PCT/GB 96/03144

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 467080 A	22-01-92	JP 4051620 A	20-02-92
		AU 632697 B	07-01-93
		AU 7848891 A	02-01-92
		CA 2044919 A,C	20-12-91
		US 5214728 A	25-05-93
EP 516363 A	02-12-92	CA 2069567 A	28-11-92
		JP 5216078 A	27-08-93